5975

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NUTRITIONAL VALUE OF SOYBEAN OIL COMPARED TO OTHER FATS AND OILS

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INTRODUCTION.

Research on dietary fat has had a spectacular resurgence over the last 5 years. Much of this resurgence was catalyzed by the correlation of omega-3 fatty acids in fish oil with reduced incidence in coronary heart disease and a lowering of plasma cholesterol and triglyceride levels (12). This data resulted in a "new found" interest in the nutritional effects of dietary fats and oils that has infected the general public and the medical professionals. This interest has "spawned" many fish oil capsule products which boast of the health benefits of omega-3 fatty acids.

In addition there are a variety of other fats and oils which are promoted as providing health benefits usually related to heart disease and cholesterol lowering. Some common examples are listed in table 1.

Table 1. EXAMPLES OF OILS ADVERTISED WITH IMPLIED HEALTH BENEFITS.

OIL	PROMOTIONAL SLOGAN
1. FISH OIL	"OMEGA-3 FATTY ACIDS HELP YOUR HEART"
2. OLIVE OIL	"MEDITERRANEAN DIET"
3. CANOLA OIL	"LOWEST IN SATURATED FATS"
4. SUNFLOWER OIL	"HIGHEST IN POLYUNSATURATED FATS"
5. CORN OIL	"THE GOODNESS OF CORN OIL"

As a result of these advertisements and numerous popular press articles, this is a very confusing time for the consumer and for health professionals and nutritionists.

The questions of interest at this conference are: 1."What is the nutritional importance of soybean oil?" and 2."How does the nutritional value of soybean oil compare to other oils in the diet?".

PRODUCTION AND CONSUMPTION OF FATS AND OILS.

The dietary impact of soybean oil is apparent from table 2 which summarizes past, present and future world production of a number of fats and oils (33).

TABLE 2: WORLD PRODUCTION OF EDIBLE FATS AND OILS IN METRIC TONS

	1980	1985	1990 (est.)		1980	1985	1990 (est.)
SOYBEAN	13.4	13.9	15.8	COCONUT	2.7	2.6	3.4
PALM	4,6	6.9	11.2	PEANUT	2.8	3.1	3.6
SUNFLOWER	5.0	6.5	8.0	OLIVE	1.6	1.5	--
RAPESEED	3.5	6.0	7.5	CORN	0.8	1.0	1.2
BUTTER	5.7	5.4	—	PALM KERNEL	0.6	0.9	1.5
TALLOW	6.3	6.6	6.8	MARINE OIL	1.2	1.5	1.5
LARD	5.0	5.3	5.7				
COTTONSEED	3.0	3.8	3.7	TOTAL	49.0	58.2	69.9

The contribution of various fats and oils to the U.S. diet is summarized in figure 1 (37).

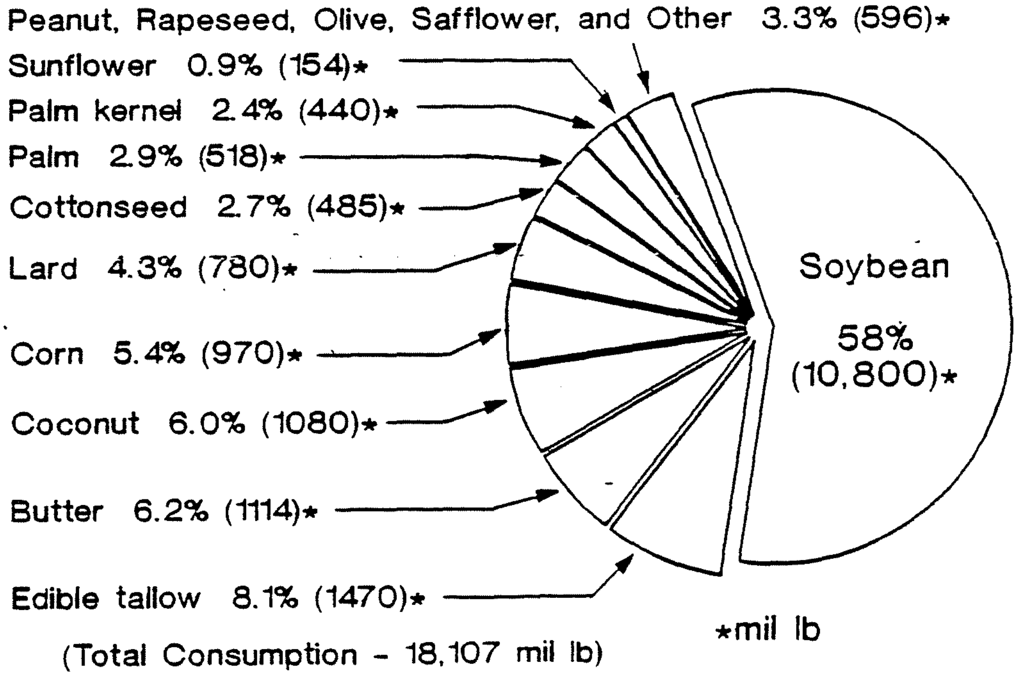


Figure 1. Consumption of Fats and Oils in the United States, 1986.

The data in figure 1 shows soybean oil as the most nutritionally important oil in the U. S. diet. Soybean oil actually provides a greater percentage of the total calories than cane sugar, corn, wheat flour, beef or any other single food item.

COMPOSITION AND ATHEROGENICITY OF FATS AND OILS.

The implied health benefits of the oils listed in table 1 are based on their fatty acid composition. The fatty acid composition of these oils and other common edible oils are compared in table 3 (53).

Table 3. APPROXIMATE FATTY ACID COMPOSITION OF EDIBLE FATS AND OILS.

FAT OR OIL	P/S RATIO	SATURATES 14:0[a]	16:0	18:0	UNSATURATED 9c-18:1	18:2w6	18:3w3
SUNFLOWER	6.57	0.0	5.5	5.0	20.5	69.0	
SOYBEAN	3.81	0.0	12.0	4.0	23.0	53.0	8.0
CORN	3.54	0.0	9.5	4.5	35.5	49.0	0.5
COTTONSEED	1.95	1.4	23.0	1.0	24.0	49.6	
PEANUT	2.00	0.0	14.0	3.0	43.0	34.0	
RAPESEED	4.00	1.0	5.0	2.0	59.0	22.0	10.0
CHICKEN	0.66	0.1	25.4	7.0	46.5	21.4	
OLIVE	0.98	0.0	11.0	2.3	73.7	13.0	
PALM	0.28	1.5	33.0	4.5	50.0	11.0	
LARD	0.27	1.5	25.0	14.0	48.5	10.0	1.0
BUTTER	0.08	24.0	29.0	11.0	30.8	5.0	0.2
TALLOW	0.08	6.3	27.4	14.1	48.2	3.0	1.0
COCONUT	0.03	76.0	10.0	4.0	7.0	3.0	
PALM KERNEL	0.04	66.0	13.0	4.0	14.0	3.0	
MENHADEN[b]	0.95	11.0	25.0	3.0	24.0	4.0	33.0

[a] Also includes shorter chain saturated fatty acids.
[b] Menhaden oil omega-3 fatty acids are mostly 20 carbon polyenes (i.e., 20:5w3 and 22:6w3).

A number of animal and human studies that have compared the atherogenicity of fat and oils but only a few references can be cited in this short review. In early studies, diets high in saturated fats were identified with hyperlipidemic effects and epidemiological studies correlated saturated fats with increased incidence of heart disease. A number of reports compared the effect of saturated fatty acids with different chain lengths and concluded that those with 12, 14, and 16 carbons (lauric, myristic, palmitic) were the most atherogenic. The lauric plus myristic acid content of coconut (64%), palm kernel (69%), and butter (11%) was proposed as the reason these oil increased cholesterol and triglyceride (TG) levels in many reported studies in animals and humans. Tallow, butter and lard contain 25 to 30% palmitic acid (16:0) which is reported to be atherogentic but to a lesser degree than 12:0 and 14:0. Palm oil contains about 46% 16:0 which would place it in this saturated fat (low P/S) group.

Subsequently, dietary fats with high linoleic acid (18:2w6) levels were correlated with a reduction in serum cholesterol and triglyceride levels. Keys and Hegstead are among many who have investigated the above fats by correlating fatty acids composition with serum cholesterol level in humans. The approximate "atherogencity values" assigned to the common fatty acids in the diet are: 3 for 12:0 and 14:0, 1 for 16:0, -0.7 for 18:2w6, and 0 for 18:0 and 18:1. (3,32,18). These values are part of the basis for many of the early health benefits claimed for vegetable oils with a high polyunsaturated /saturated fatty acid ratio (P/S).

More recently, oils with a high oleic acid content were reported to have cholesterol lowering properties similar to the high linoleic acid oils but with the added benefit that the "good" high density lipoprotein (HDL) cholesterol levels were not reduced (31). Low eurcic acid rapeseed oil (Canola) was reported to reduce čholesterol levels in French farmers and raise HDL cholesterol levels in their wives (41). The reason for this result is not clear but suggestions include the low saturated fatty acid content, the high oleic acid and linoleic acid content, the 18:3w3 content or a combination of all three factors. The 18:2 content of the diet correlated most strongly with lower cholesterol levels. Others have also reported that 18:3 lowers the reactivity of platelets to compounds that stimulate platelet aggregation (40,7). This observation is considered to have a positive cardiovascular benefit.

Diets containing peanut oil do not increase serum cholesterol levels but this oil is reported to be the most atherogenic of the high polyunsaturated fatty acids (PUFA) oils (26). Interesterification of peanut oil (26) and oils containing 12:0 and 14:0 (18) reduce their atherogenic properties. The reason is unknown but it may be related to triglyceride structure or to the presence of lectin in peanut oil (24).

Soybean oil has a high 18:2w6 content, contains the omega-3 fatty acid (18:3w3) as does Canola, and has about the same amount (10 -11%) of 16:0 as corn oil. Thus, the ratio of saturated: oleic: omega-6: omega-3 fatty acids in soybean oil compares favorably with that of canola oil and other high PUFA oils that have been touted as having health and nutritional benefits.

HYDROGENATED OILS.

The fatty acid composition of vegetable and animal oils is substantially modified by the hydrogenation process which is used to produce semi-solid fats for margarines and shortenings. As shown in table 4, the main effect of hydrogenation on fatty acid composition of soybean oil and menhaden oil is to reduce the levels of polyunsaturated fatty acids, increase the saturated fatty acids, and form cis and trans positional isomers (21,49). Note that the highly publicized omega-3 fatty acids in fish oil are destroyed by hydrogenation.

Table 4: Composition of Refined and Partially Hydrogenated Soybean Oil and Menhaden Oil a.

OIL	IV	TRANS	SATURATES	MONOENES	DIENES	TRIENES	20:5W3	22:6W3
REFINED SOYBEAN	154	0.0	16.0	22.0	53.5	8.0	--	--
HYDRO. SOYBEAN	119	22.0	18.0	45.0	32.0	2.0	--	--
REFINED MENHADEN	159	0.0	38.3	23.5	4.0	4.2	12.5	9.0
HYDRO. MENHADEN	90	41.0	39.3	32.0	10.5	10.9	0.0	0.0

a. Percentages for the unsaturated fatty acids in the hydrogenated samples include cis and trans isomers.

The nutritional effect and metabolism of isomeric fatty acids on have been extensively investigated and reviewed. (50,15,14,4). Consumption of hydrogenated vegetable oils have little effect on plasma cholesterol levels as long as the diet contains adequate levels of linoleic acid (4).

Analysis of a typical human adipose tissue sample is shown in figure 2 and indicates the levels of isomeric fatty acids are proportional to the levels in the diet. No correlation of isomeric fatty acids with heart disease riskfactors was found for a group of samples from middle age U.S. male subjects (unpublished data) and for samples from British male subjects (54).

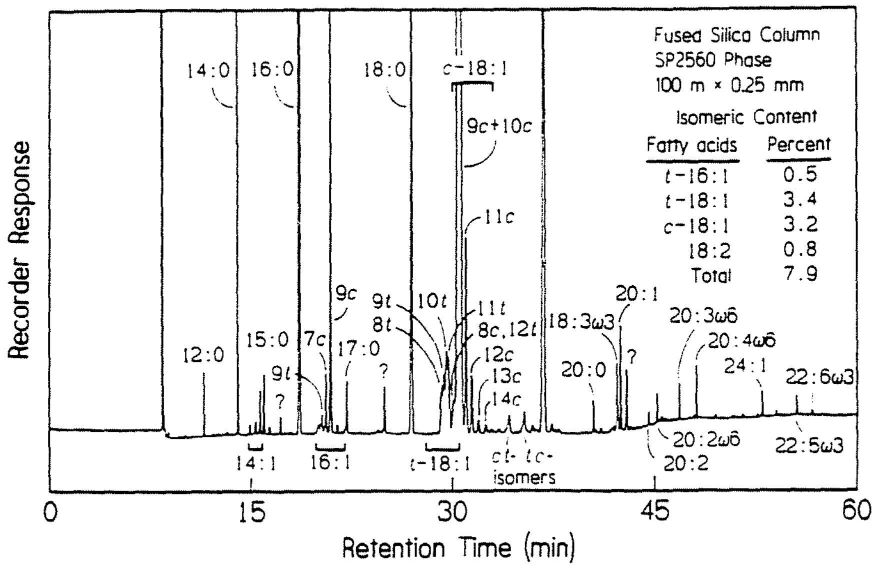


Figure 2: Typical Fatty Acid Composition of Adipose Tissue From U.S. Males

Analysis of a variety of other tissue lipids found levels of isomeric fatty acids to be lower than in adipose tissue (36,1). These data show no evidence for accumulation of isomeric fatty acids in any tissue lipid class.

The data for human plasma lipids shown in figure 3 was obtained by feeding mixtures of triglycerides containing deuterium-labeled isomeric fatty acids to young adult male subjects (16).

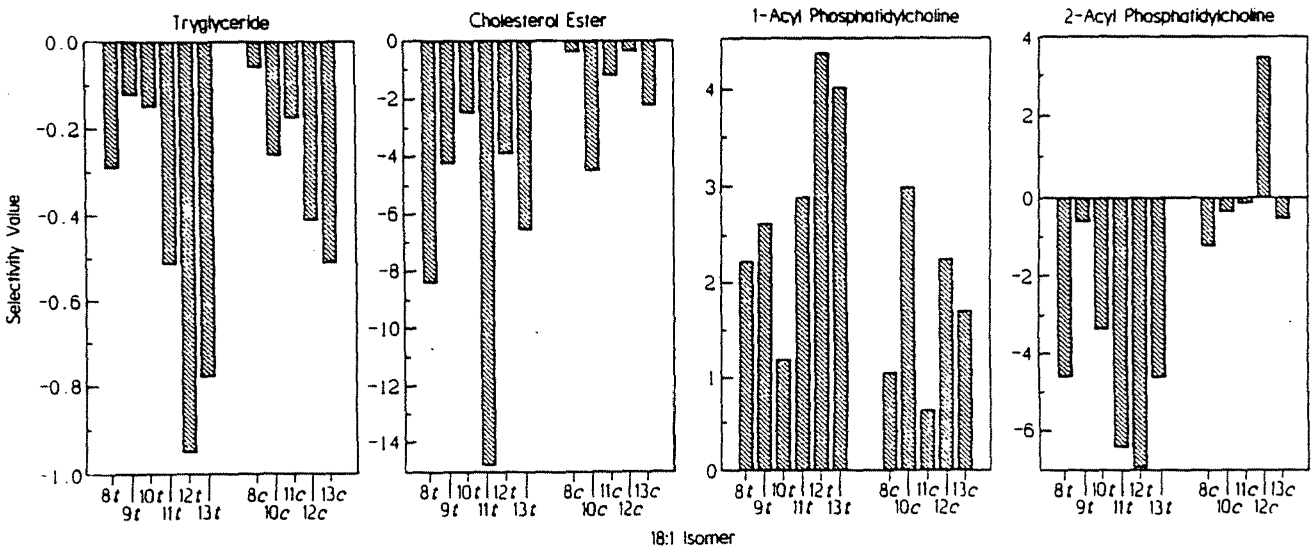


Figure 3: Human Plasma Lipids: Selectivity Values for trans and cis Positional Octadecenoic Acid Isomers Relative to Oleic Acid.

The selectivity data show the isomeric fatty acids have metabolic characteristics intermediate between 18:0 and 9c-18:1. The combined tissue data and the isotope data indicate that isomeric fatty acids are preferentially used for energy. A review of the health aspects of isomeric fatty acids conducted for FDA (50) concluded the nutritional impact of partially hydrogenated vegetable oils was similar to other dietary fats and oils.

MINOR CONSTITUENTS.

All edible vegetable oils contain a variety of minor constituents. In addition animal fats contain cholesterol which has caused in these fats to receive considerable negative press but there is really no conclusive data to support the view that cholesterol in animal fats contribute significantly to vascular disease. Some of the minor constituents in selected fats and oils are listed in table 5 (53).

Table 5: MINOR CONSTITUENTS IN FATS AND OILS: a

	STEROLS TOTAL %	VIT. E TOTAL %	SQUALENE %		STEROLS TOTAL %	VIT. E TOTAL %	SQUALENE %
SOYBEAN	0.45	0.095	0.012	COCONUT	0.07	0.008	0.002
PALM	0.03	0.056	---	PEANUT	0.22	0.048	0.028
SUNFLOWER	0.62	0.073	0.012	OLIVE	0.30	0.020	0.383
RAPESEED	0.45	0.066	0.026	CORN	1.00	0.090	0.028
BUTTER	0.40	0.003	---	PALM KERNEL	0.10	---	---
LARD	0.11	0.001	---	TALLOW	0.10	0.001	---
COTTONSEED	0.40	0.090	0.008				

a. Amounts vary depending on the refining conditions used, variety and location grown.
b. Total sterols: esterified and free sitosterol, stigmasterol, campesterol, brassicasterol, avenasterol, spinasterol, ergosterol, cholesterol. Sitosterol and campesterol are main sterols in vegetable oils.
c. Vit. E = total tocopherols: includes alpha, beta, gamma, and delta isomers.

The high tocopherol (vitamin E) level in many vegetable oils is a positive health factor, as is the carotene content which is a precursor for vitamin D. Refined vegetable oils generally contain less than 0.05% triterpene alcohols and terpenoid hydrocarbons. Cottonseed oil contains gossypols and cyclopropenoic acids which have negative physiological impact if large amounts are consumed. Polycyclic aromatic hydrocarbons have been identified in vegetable oils (29). These compounds are a potential health hazard since some are potent carcinogens.

OMEGA-3 FATTY ACIDS.

The omega-3 fatty acids (20:5w3 and 22:6w3) in fish oils and 18:3w3 from vegetable oils have been intensively studied since 1979 when it was reported that a low incidence of coronary heart disease in Greenland eskimos was correlated with a diet high in fish oil (12). Since that time, omega-3 fatty acids have been reported to have a wide variety of health benefits. Examples of some of these health benefits and a few selected references are listed in table 6. Most of the data is from studies with fish oils and the physiological effects are attributed to the 20:5w3 and 22:6w3 fatty acids rather than 18:3w3.

Table 6. HEALTH BENEFITS REPORTED TO BE ASSOCIATED WITH OILS CONTAINING OMEGA-3 FATTY ACIDS

BENEFIT	REFERENCE
1. LOWER SERUM CHOLESTEROL LEVELS	41,25,43
2. LOWER SERUM TRIGLYCERIDE LEVELS	48,2
3. LOWER BLOOD PRESSURE	20,51
4. LOWER PLATELET AGGREGATION	41,7,47
5. IMPROVED LEARNING AND MEMORY	45,34,28,35,56
6. VISUAL ACUITY	34,38
7. IMMUNO RESPONSE	42,23
8. DECREASE IN CANCER CELL GROWTH	17,8
9. DECREASE IN HEART DISEASE MORTALITY	12,13,27
10. IMPROVEMENT IN RHEUMATOID ARTHRITIS SYMPTOMS	52
11. DECREASE IN ATTACKS OF ANGINA	19
12. MULTIPLE SCLEROSIS	10

A current question is "Does the 18:3w3 fatty acid in soybean oil have health benefits similar to the fish oil omega-3 fatty acids"? It is known that 18:3w3 is converted to 20:5w3 and 22:6w3 in many mammalian species. The biological pathways have been identified and are compared in figure 4 to the conversion of 18:2w6 to 20:4w6 and 22:5w6.

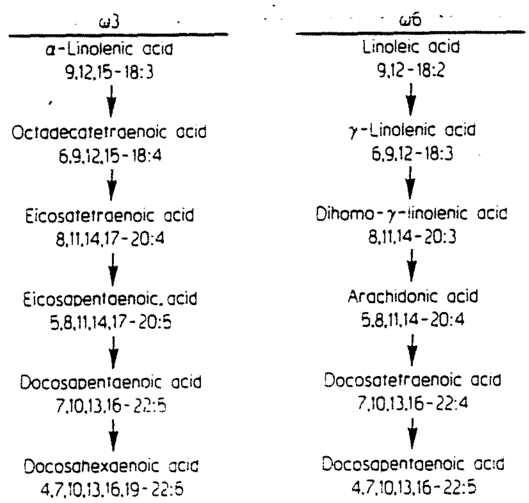


Figure 4: Pathways for conversion of 9c,12c-18:2 and 9c,12c,15c-18:3 to long chain omega-3 and omega-6 fatty acids.

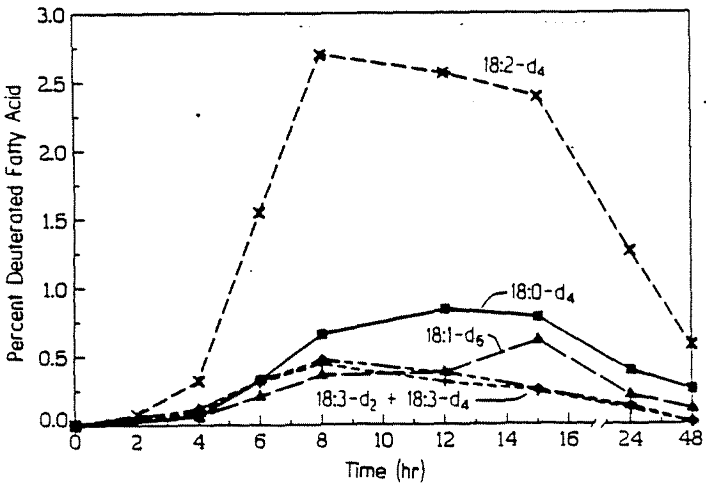
Both 18:2w6 and 18:3w3 are essential fatty acids because humans can not synthesize a delta 12 double bond. Human requirements for 18:3w3 has been estimated at 0.5% to 1.0% of calories (22,30) and/or 300 to 400 mg per day (5). The requirement for 18:3w3 is considered to be highest for infants due to the rapid growth of brain and nerve cells.

It is well known that high levels of the 20:5w3 and /or 22:6w3 are present in retina, testes, and nerve lipids (44,39,35,55,6). Also, there is evidence that these fatty acids are highly conserved in these tissues (35,55). The data suggest these fatty acids are necessary for the normal transmission of neurological signals in these tissues.

Tissue data for vegetarians (46) provide indirect evidence that suggests humans are capable of converting both 18:2 and 18:3 to the longer chain polyene acids shown in figure 4. However, the level of 18:3 in human tissue lipids is much lower than would be predicted based on estimated intake. Diets containing 20 ml/day of linseed oil elevate the percent of 18:3 in platelet phospholipids by only 0.3 %. (47) and 60 ml/ day of linseed oil increased 20:5w3 in plasma lipids by about 2 % (7).

In comparison, the 18:2 levels are relatively high in most tissue lipids. Animal and cell culture data suggests the conversion rates are controlled and that the ratio of the various fatty acids in the diet influence these conversion rates (9). A variety of evidence suggests the biological mechanisms that control tissue lipid composition are: 1) modification of dietary fat composition by endogenous fat during absorption, 2) selective oxidation, 3) acyltransferase enzyme selectivities, and 4) variation in desaturase and elongase enzyme activities. We are currently attempting to measure the conversion rates for 18:2 and 18:3 in humans and to determine the metabolic fate and distribution of dietary 18:3 by feeding mixtures of deuterium-labeled fatty acids.

The preliminary results shown in figure 5 indicate that 18:2w6 incorporation into plasma phospholipids is about 5 times higher than for 18:3w3. Deuterated 18:0, 18:1 and 18:3w3 are incorporated at similar levels which is very surprising if the difference in structure is considered.



Tryglyceride Mixture Fed:

	Wt. (g)	%
18:0 d_4	3.4	20.5
9c-18:1-d_6	3.4	17.5
9c,12c-18:2-d_4	2.9	20.5
9c,12c,15c-18:3-d_4	3.4	20.5
9c,12c,15c-18:3-d_2	3.5	21.1
Total	16.6	

Figure 5. Incorporation of deuterium-labeled 18:3w3 compared to other common dietary fats in human plasma phosphatidylcholine.

Chain elongation and desaturation products were not detectable in any of the plasma lipid fractions and suggests that 18:3 is oxidized at a higher rate than 18:2w6. A high oxidation rate for 18:3w3 has also been reported in rats for radioisotope labeled 18:3w3 (11). The conversion rates for 18:2w6 and 18:3w3 to 20:4w6 and 20:5w3 in humans appears to be at least 100 times slower than in our mouse and cell culture models.

The plasma cholesterol ester data (figure 6) indicate about a 9 fold higher level of incorporation for 18:2w6 than for 18:3w3 or 18:1w9.

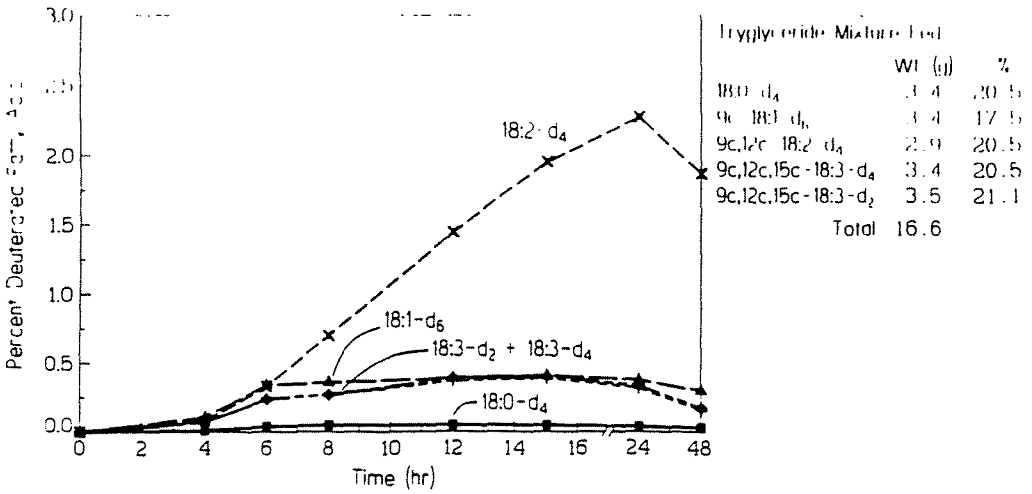


Figure 6. Incorporation of deuterium-labeled 18:3w3 compared to other common dietary fats in human plasma cholesterol ester.

The results in figures 5 and 6 are preliminary data but they the only human data avaible that provide a direct comparison of the metabolism of stearic, oleic, linoleic and linolenic acid. These results are direct evidence for a large differences in the selectivities of the acyltransferase enzymes for various fatty acids structures. The relatively low incorporation of 18:3w3 compared to 18:2w6 is unexpected since the only structural difference is one additional double bond. These data indicate the acyltransferases have an important role in regulation of the fatty acid composition of phospholipids and cholesterol ester. These large differences in metabolism of the omega-3 and omega-6 polyunsaturated fatty acids suggest physiological importance which supports the observations of others. The mechanism and pharmacological significance of the omega-3 fatty acids still remain to be established.

SUMMARY.

There is considerable evidence that the body regulates the fatty acid composition of cell membranes and lipid levels and that this regulation is genetically controlled. Thus, in normal individuals, varying the fatty acid composition of the dietary fat would be expected to have much less impact on health than suggested by advertisements in the lay press. Certainly there is a dietary fatty acid ratio that will produce optiminal health benefits but humans have the ability to selectively use the various fats in the diet to meet requirements and to compensate for a wide variation in dietary fatty acid intake. In the U.S., soybean oil supplies an estimated 1.7 g of 18:3w3 per person per day (ca. 0.6% of the total calories) which is sufficient to meet normal requirements. It still remains to be determined if there are real health and nutritional benefits associated with 18:3w3 and if so, what is the biochemical basis.

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